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NATURAL CHANGE IN THE ENVIRONMENT: A CHALLENGE TO THE PRESSURE-STATE-RESPONSE CONCEPT

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ABSTRACT: The pressure-state-response framework is a powerful approach to environmental assessment. In many of its current expressions, however, it ignores the background natural processes that play a major role in determining environmental and ecosystem health. Clearly, policies must be focused on human actions that scar the landscape and harm the environment, but coping with environmental change also requires an assessment of the natural processes that take place whether or not human influences are at work. A newly-developed class of environmental indicators (geoindicators), presented here in brief, may be helpful in understanding the interaction of human and natural processes and impacts. Explicit recognition of the need to include natural conditions in the indicator system is essential in the transition from environmental reporting to sustainability reporting.

1 INTRODUCTION: THE DEVELOPMENT OF THE CONCEPT

A large number of models of the relationship between humans and ecosystems lies scattered throughout the literature. Thirty of these are reviewed in Hodge (1995a, and 1997), including the stress-response framework for environmental statistics.

The concept of stress at the interface between the human and the ecosystem (environment) was first introduced in the 1950s as describing something acting on and influencing human well-being. Examples include the stress on people caused by disasters (Jams, 1954) or human migration as an adjustment to environmental stress (Wolpert, 1966). Kasperson (1969) extended this early work by examining the broad influence of environmental stress on municipal decision-making. He defines stress as "noxious or potential noxious environmental forces upon the individual" and the resultant strain as "the individual's perception, evaluation and reaction to the stimulus" (1969: p. 484).

More recently, an important conceptual advance has emerged from state-of-the-environment reporting. When faced with growing criticism of the limitations of traditional economic reporting, the UN Statistical Office began in the mid-1970s to develop a general framework of environmental statistics. A joint initiative with Canada led to the development of the Stress-Response Environmental Statistical System (STRESS) within Statistics Canada (Rapport and Friend 1979; Friend and Rapport, 1989). By means of concepts of environmental stress and environmental response, this

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focuses on the interface between production-consumption activities of humans and the transformation of the state of the environment. Four categories of statistics are identified, dealing with activity stressors, environmental stresses, environmental responses, and collective and individual human responses. Within a proposed "Information System for Sustainable Development" Friend and Rapport (1989) link indicators of environmental stress and response (through STRESS) with indicators of economic performance and indicators of demand and supply of natural resources.

The stress-response approach has had a major impact on environmental reporting around the world (Hodge, 1991). This can be seen in the current DECD approach to environmental policy analysis: pressure - state of the environment- socioeconomic consequences - policy response (Pearce and Freeman, 1992; Comolet, 1992). UNEP and UNCSD now use a variant called the driving forces (pressure)state-response (DSR) framework (UNEP and DPCSD, 1995), in which driving forces are "human activities, processes and patterns" that have an impact on the environment.

It should be noted that earlier stress-response frameworks included natural (non-human) as well as human influences. In their list of environmental stresses, Rapport and Friend (1979) incorporated a category for "extreme natural events" such as storms, floods, drought, volcanic eruptions, earthquakes, land-slides and outbreaks of disease. Recognition of natural stresses is retained in some contemporary expositions of the indicator framework (e.g. Saskatchewan, 1992; Freedman, Staicer and Woodley, 1995) but, for the most part, the focus is now on the effects of human actions on the environment. This is particularly evident in the list of indicators that has received some degree of official status from the United Nations Committee on Sustainable Development. The exclusion of natural influences is but one of several serious limitations to current expressions of the stress-response concept, one that reduces significantly its usefulness for sustainability reporting and assessment.

2 DISTINGUISHING HUMAN FROM NATURAL STRESSES AND CHANGE

The condition of the environment at any time reflects not only human influences but-also natural processes and phenomena, which may be causing change whether or not people are present. The long evolutionary history of the Earth and the biosphere has been punctuated throughout by environmental changes, both rapid-onset (e.g. volcanic eruptions, floods) and more gradual (e.g. river and coastal erosion, glacier advance and retreat, ground subsidence). Many of these changes have reduced the capacity of terrestrial ecosystems to provide a place for healthy life, whatever the organism. Away from obvious sources of human disturbance (cities, waste disposal sites, mines, forested areas), it may be extraordinarily difficult to separate the effects of human actions from those due to the "background" natural processes.

A new compiled checklist (cf. the "core menu" of CSD, 1995) of geological indicators of rapid environmental change illustrates this point (Berger and lams', .1996). Listed here are 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be of significance for environmental sustainability and ecological health. Geoindicators have been developed as tools to assist in integrated assessment of natural environments and ecosystems, as well as for state-of-the-environment reporting. They describe common earth processes that operate in one terrestrial setting or another, and represent collectively a new kind of landscape metric, one that concentrates on the non-living components of the lithosphere, pedosphere, hydrosphere, and their interactions with the atmosphere, biosphere (including humans).

Table I illustrates in a general way the degree to which each geoindicator is influenced by natural (non-human) processes and by direct human activities. Except for soil quality and groundwater quality and level, all the processes and their outcomes described by geoindicators are subject to change, whether or not humans are present. Indeed, these are the major ways in which landscapes have developed and evolved throughout time. There is no question that dust storms, glacier advance and retreat, surface uplift and subsidence, and stream sediment storage and discharge, for example, have operated as integral components of nature throughout the long evolution of our planet. Now, however, human actions can have a direct impact upon most natural processes, and these influences become more marked as populations increase and economic growth proceeds.

It may be very difficult to separate in any particular environment or ecosystem the effects of nature from those of humans. Even in remote, unpopulated areas, there may be indirect, far-travelled human influences, such as long-range aerial transport of acid pollutants or human-induced climate warming. Groundwater plumes from waste disposal sites or other point-sources of pollution are clearly anthropogenic, as are changes in fluvial systems (e.g. stream channel morphology, stream sediment storage and discharge) related to dams and reservoirs; irrigation systems, and river diversions. Even earthquakes can be induced by surface loading of water in reservoirs, or around oil fields where hydrocarbons are pumped from the subsurface. But how does one separate out human trends from natural ones? For example, the underground dissolution of limestone, which leads to the development of collapse features such as sinkholes, is always at work, so that it may not be possible to be certain in a karst terrain of the added effect of increased water extraction for human use.

None of this is to argue, as some do, that a laissez faire attitude to environmental regulation is best, that we might as well do what we like because nature is unpredictable. Clearly, harmful human stresses on the environment must be curbed, if only for the sake of prudence: The challenge is to deal with both human influences, which may be predicted and controlled, and natural ones that cannot.

TABLE I
Natural vs human influence on geoindicator change in less than 100 years

GEOINDICATOR	Natural Influence	Human Influence
Coral chemistry and growth patterns	■	■
Desert surface crusts and fissures	■	□
Dune formation and reactivation	■	□
Dust-storm magnitude, duration and frequency	■	□
Frozen ground activity	■	□
Glacier fluctuations	■	○
Groundwater quality	□	■
Gw chemistry in the unsaturated zone	■	■
Groundwater level	□	■
Karst activity	■	□
Lake levels and salinity	■	■
Relative sea level	■	□
Sediment sequence and composition	■	■
Seismicity	■	□
Shoreline position	■	■
Slope failure (landslides)	■	■
Soil and sediment erosion	■	■
Soil quality	□	■
Streamflow	■	■
Stream channel morphology	■	■
Stream sediment storage and load	■	■
Subsurface temperature regime	■	□
Surface displacement	■	□
Surface water quality	■	■
Volcanic unrest	■	○
Wetlands extent, structure and hydrology	■	■
Wind erosion	■	□

■ - Strong influence □ - Potential influence ○ - No substantial influence

N.B. This table illustrates in a general way the relative roles of natural and human-induced changes, both dint and indirect, in modifying the landscape and earth (geological) systems. However, it excludes from consideration influences that may be brought about by anthropogenically-induced climate change.

3 THE PROBLEM OF SEPARATING SYSTEM COMPONENTS

Even if human and natural stresses can be distinguished in any particular environment, the response to any imposed stress, whatever its source, may from another perspective be a stress on a different part of the ecosystem (cf. UNEP and DPCSD, 1995: p. 6). In many circumstances, specific responses cannot be linked to specific stresses. In complex systems, this leads to an inevitable trickle-down effect that is the cause of much confusion: there is rarely a single identifiable response. As Noss (1990) puts it "effects of environmental stresses will be expressed in different ways at different levels of biological organization. Effects at one level can be expected to reverberate through other levels, often in unpredictable ways: "

A volcanic eruption may perturb local and regional ecosystems, through impacts on regional weather patterns and global air quality, local slope stability, fluvial systems, subsurface temperatures regimes, soil quality, glaciers, and hillslope erosion. Likewise, lacustrine ecosystems are affected by changes in lake levels which maybe intimately connected with climate change, fluctuations in groundwater levels and quality, frozen ground activity, wind erosion, or dust storms. Rising or falling relative sea levels influence shoreline position and coastal and estuarine environments, and they may also perturb local streamflow and groundwater quality, and cause surface uplift or subsidence. Establishing cause and effect may be next to impossible in such multi-component systems.

4 THE LANGUAGE GAP

The language of the DSR approach may not facilitate smooth linking with public policy and decision-making. Indeed, the uncertainty resulting from lack of clear cause-effect linkages should be seen as an inherent characteristic of contemporary decision-making, not as an impediment. The ecosystem itself integrates the effects of many simultaneously-induced stresses, and assessments of cumulative effects should turn to the ecosystem.

In natural ecosystems, environmental stress may be defined as a forcing phenomenon causing perturbation or disturbance, some of which may be debilitating to the ecosystem, though others, like wildfire, may be rejuvenating. Low levels of cumulative stress may not necessarily be "bad", but may lead to an invigorated ecosystem. As Holling has argued (1986) ecosystem health may be more tied to an ecosystem's ability to use stress creatively (its resilience) than to its ability to resist stress completely.

An example of the terminological difficulties can be found in the 1992 SOE report for Saskatchewan. Here *environmental condition* refers to "baseline" state as judged from areas relatively unaffected by direct human activity. *Stress* (pressure) describes "the intensity and extent of natural and human factors that affect environmental conditions", and *response* deals with the impact of stresses on the environment and assesses the "human actions undertaken to protect the environment." Proposed indicators of condition include surface water chemistry, lake levels over time, and the area covered by wetlands. Yet, stream sediment storage and discharge, volume of soils eroded by wind and water, nutrient levels in water, and aspects of streamflow are all regarded as stress indicators, even though-such parameters also operate and fluctuate in natural areas (cf. Table 1). Moreover, as regards groundwater, nitrate levels and number of licensed users are classed as indicators of stress rather than of response to policies. In a system where each process and situation influences and is, in turn, influenced by many others, how can one separate out condition, stress and response?

5 OTHER LIMITATIONS

There two other weaknesses of the DSR approach that are not easily overcome.

5.1 Anticipatory Capacity

The DSR approach works best when an environmental issue has been identified and linked to a causative set of human activities. Policies and programs have been put into place to control the known relationship, and performance indicators are chosen to track the success of the policy. This sequence is reactive, rather than anticipatory in nature. It falls into place after the issue of concern has been established.

In some situations, however, identifying environmental stresses and their trends may provide a guide to future results, as in monitoring the volcanic unrest that leads to eventual eruption and landscape perturbation. However, there are other circumstances where environmental changes are not predictable, at least not at our present level of understanding. For example, the identification of seismic activity is not likely to assist in predicting or forecasting the timing, exact location, or intensity of an eventual earthquake. The best we can do in many stressed environmental situations may be to recognize warning signs and adjust societal actions before they become crises.

The real need in terms of achieving progress toward sustainability is to achieve some degree of anticipatory capacity so that issues can be recognized before they become concerns – not simply reacted to after they reach crisis proportions. The DSR approach does not encourage development of such a capability.

5.2 Benefits from Environmental Stresses

The DSR approach also fails to distinguish beneficial from harmful environmental stresses and impacts. River flooding of farmlands may destroy crops and property, but it may also be the main source of new nutrients to enhance the productivity of the same fields. Wildfires destroy forests, plants, animals, and property, but it is now recognized that they may also be required for forest regeneration a situation that presents a major dilemma for those responsible for managing forest ecosystems. Should the management of a forested national park suppress, encourage, or even initiate burning? Indeed, taking the long-term view of earth evolution, it can be argued that any natural stress and the change it initiates may have both beneficial and harmful effects, at least in terms of the health of the living organisms that survive.

6 WHERE DO WE GO FROM HERE?

Sustainability is a bridging concept that recognizes the need to pursue human and ecological well-being together: it is an explicit statement of interdependence. The "anthropoblamist" perspective that sees all environmental conditions, stresses and responses as caused only by human actions misses a significant part of the human-ecosystem "equation." At the end of the twentieth century, the pace of change has increased enormously, and humans have made powerful impacts on virtually all environments. Clearly, many of these stresses must be avoided or removed if human life is to be sustained and improved. At every step in the process of assessing the state of the environment, however, natural processes, which operate today as they have throughout time immemorial, must be recognized.

Monitoring progress should, therefore, include one set of data and information dealing with human conditions and another dealing with ecosystem conditions. A third set of data and information describes the nature of human activities, which provide for society's well-being, stress the ecosystem, and, increasingly, serve to restore degraded ecosystem functions. This third data set should also recognize interactions between humans and the environment by dealing with the influences, both beneficial and harmful, exerted upon society by the natural environment. A fourth, over-arching set of data and information is also required. This provides more than a simple synthesis by facilitating the recognition of emergent (otherwise unrecognized) system properties. It also provides an integrated perspective for decision-making and anticipatory analysis. These four areas of diagnosis or indicator domains reflect a systems approach to the issue of monitoring progress toward sustainability (Hodge, 1993,1995a, b; NRTEE, 1993).

Framing the reporting system in this way offers three advantages.

1. There is an explicit link to the goal of pursuing human and ecosystem well-being together.

2. It recognizes that people are part of the environment/ecosystem, although for the purposes of analysis they are held separately.

3. It stresses that what has to be managed is human activity.

From a monitoring and reporting perspective, the first of these is critical. To provide an assessment of progress, any set of indicators must be nested in and explicitly connected within a goals framework. The second leads to a need for compiling signals about both human and ecosystem conditions. It underlines the need to be as concerned with "natural conditions" as with the changes wrought by human activity. The third is no less important because of the long-held view that people can "manage" the environment. Such a view, because it offers a false premise, can only lead to misplaced policies. Society can only manage the activities of people, through policies, laws, and regulations, and the human actions, in turn, influence and are influenced by the ecosystem in which they are set.

State-of-the-environment reporting generally focuses on the harmful aspects of the human-ecosystem relationship. Expanding the scope by including measures of human activity offers the opportunity to portray and assess the benefits achieved by what people do to the ecosystem, and what the ecosystem contributes to human well-being.

Progress toward sustainability requires a full systems approach that is based on a recognition that human and environmental (ecosystem) well-being is to be sought as an interlinked goal. In turn, this goal must drive our reporting systems, if they are to contribute to the development of an anticipatory capacity in support of improved decision-making.

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